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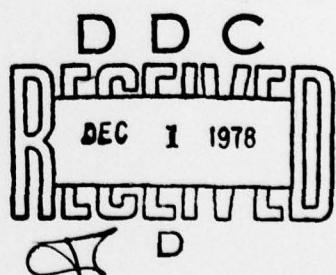
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Ultrasonic Measurement of Motor Case Insulation Thickness

S.D. HART

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September 1978



**NAVAL RESEARCH LABORATORY
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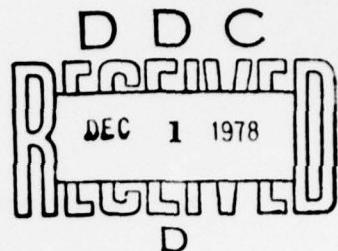
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ULTRASONIC MEASUREMENT OF MOTOR CASE INSULATION THICKNESS

INTRODUCTION

An ultrasonic technique for measuring the insulator thickness of a Kevlar epoxy missile motor case before and after firing has been devised. Tangential radiography could be used, but it is expensive, and delineation of interfaces is somewhat uncertain because the x-ray beam is broad and looks through chords as well as the tangent. An ultrasonic approach offered promise because it is simple, quick and inexpensive. This report shows that ultrasonics can be used to measure the insulator thickness from the outside surface of motor case both before and after firing, and possibly during firing.

APPROACH

The motor case is built of Kevlar fiber reinforced epoxy and the insulator is EPDM rubber. The ultrasonic approach is to send a pulse of ultrasound through the motor case and observe echoes from the motor case-insulator interface and from the free surface of the insulator. Figure 1 shows the ultrasonic probe used and Figures 2a and 2b show oscilloscope traces of the echoes. Separation of these echoes in time depends on the velocity of ultrasound in the EPDM. The ability to resolve these echoes is a quality the instrumentation. The purpose of the stand-off, or delay line, in Figure 1 is to aid in this resolution by giving the very strong transmitted pulse (or "Main Bang") time to die out before echoes return. There is an echo

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from the delay line-Kevlar interface but it is not nearly so strong as the Main Bang. A typical oscillogram is shown in Figure 2a. The echo at the left comes from the delay line-Kevlar interface. The echo at 2.6 is from the Kevlar-insulator interface and the one at 4.2 is from the free surface of the insulator.

This was taken on a piece of unfired motor case. In Figure 2b echoes from equivalent interfaces of a piece of fired motor case are shown. However, the third echo does not actually come from the free surface of the insulator. After firing, the free surface is not only charred, but is porous to a depth of approximately a millimeter. The third echo in this case comes from the interface between the remaining solid and the porous layer. Figure 3 shows these layers and part of the Kevlar-epoxy motor case. The fact that the ultrasound reflects from this porous layer interface is of course the best of information, for it is the amount of insulation remaining after firing that is of interest. It may be noticed that the two echoes of interest appear at different locations on the base line. This is due to the fact that the Kevlar is thicker in the second case. The baseline calibration is 2 μ seconds per division in both oscillograms.

Such good clear indications are not attainable at all locations on the motor case. There are places where no Kevlar-insulator interface echo appears, due to poor transmission in the Kevlar. Once a good location is found, the probe assembly or at least the delay line should be fastened on and left there during firing. A high temperature couplant might be needed.

INSTRUMENTATION

Figures 2a and 2b are oscillograms taken from a Krautkramer USIP-11 ultrasonic instrument. The transducer was a Holosonics 9.5 mm, 3 MHz, untuned, with a piezo-ceramic element, designed for immersed operation. The USIP-11 was operated in the 2-8 MHz band. It was found that untuned transducers are necessary because the tuned units ring too long for

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resolution of the two echoes. A water delay line was used in our test because it is convenient. Coupling is uniform, and it is easy to move about. Satisfactory echoes were obtained with a Lucite delay line but it was not convenient to move about. High temperature plastic might have to be used for application during firing. 2.25 MHz untuned transducers also gave good results. Other ultrasonic instruments and untuned transducers also performed satisfactorily, but not as well as the USIP-11 with the Holosonics transducer.

The velocity of ultrasound in the unfired and fired insulators was measured. This was done by measuring the time between the echoes from Kevlar-insulator interface and the insulator surface or the solid-porous layer interface. The velocities were 0.15mm/ μ sec for the unfired, and 0.16 mm/ μ sec for the fired. In the case of the fired insulator, the porous layer was sliced off to verify that the echo does indeed come from the porous-solid interface.

It may also be of interest to note that it was possible to peel the unfired insulator from the Kevlar, but impossible to peel the fired rubber off. It is not known whether firing helped to produce a stronger bond or that the unfired one was just an example of a weak bond.

The time between echoes was measured by calibrating the time base of the ultrasonic test instrument by inserting accurate time markers from an Ultrasonic Electronic Test Block (ETB) [1,2,3]. The ETB produces a pair of pulses the separation of which can be set in increments of $0.1 \pm .01 \mu$ sec. When these two pulses are positioned at the same places on the time base as the motor case echoes the time separation can be read directly from the ETB. Alternatively, the USIP-11 time base can be adjusted so that the graticule markings correspond to the time set into the ETB.

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CONCLUSIONS

It has been shown that insulator thickness can be measured ultrasonically from the outside surface of the motor case. Not enough measurements were made to establish accuracy limits but there can be reasonable confidence in measurements made at the exact same place before and after firing. An easy way to do this would be to cement the stand-off in place. An estimate of the lower limit of insulator thickness that can be measured can be made from a study of Figures 2a and 2b. The thickness shown there is 2.8 mm. The spacing could be much closer, say equivalent to 0.5 mm, and still be measurable.

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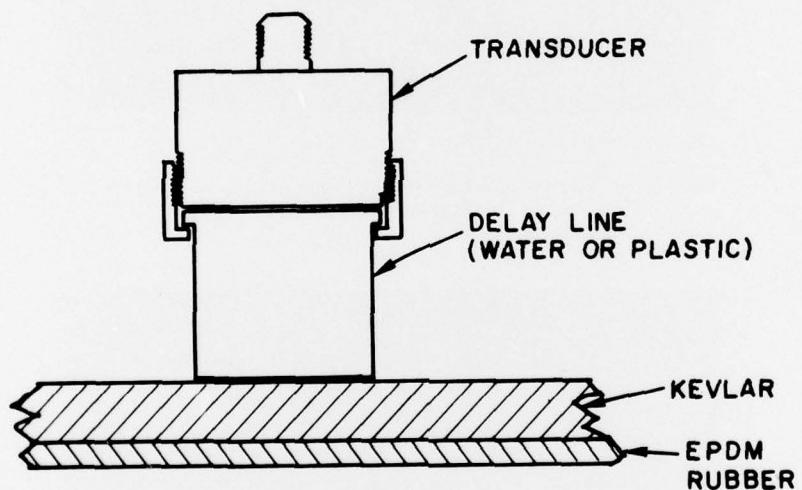


Fig. 1 — Probe for insulator thickness measurement

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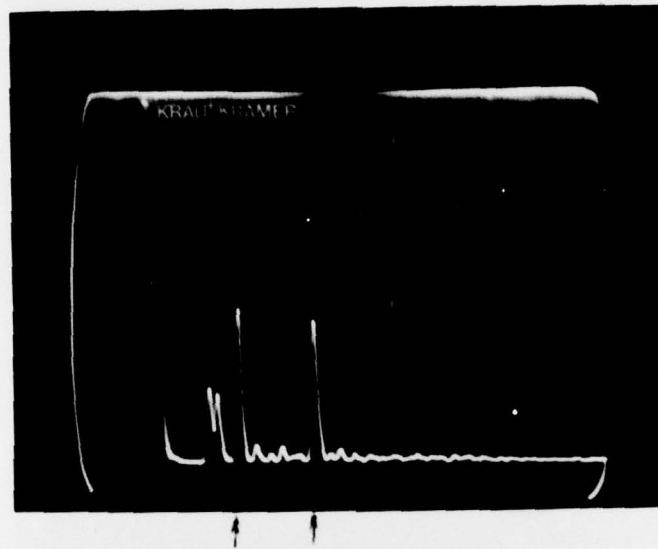


Fig. 2a - Echoes from case-liner interface and from inner surface
Unfired motor case.

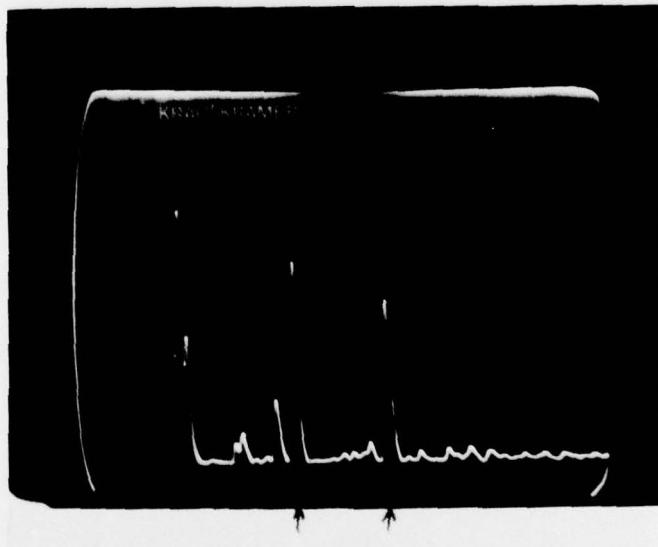


Fig. 2b - Echoes from case-liner interface and porous layer.
Fired motor case.

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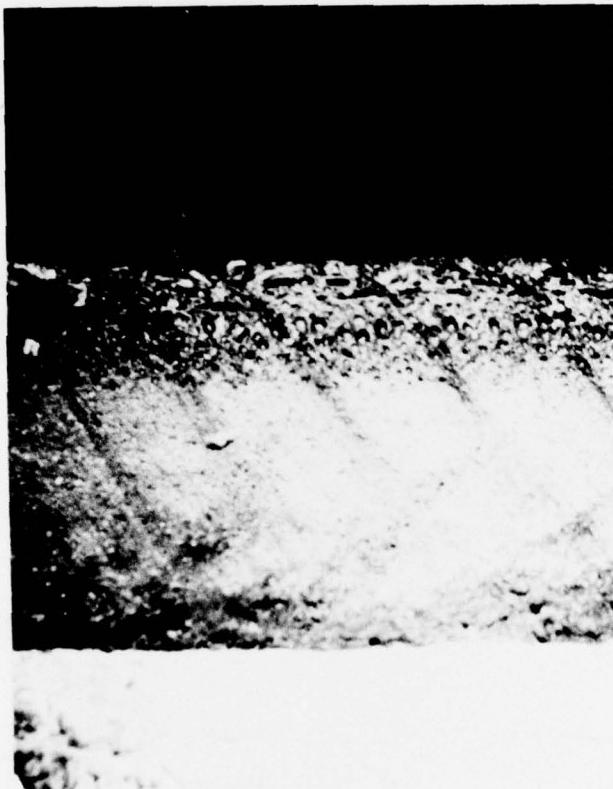


Fig. 3 — Porous layer on inner surface of liner after firing.
White part at bottom is Kevlar — Fired motor case.